

PHENIX results on elliptic and triangular flow at midrapidity in d+Au collisions from 19.6 to 200 GeV

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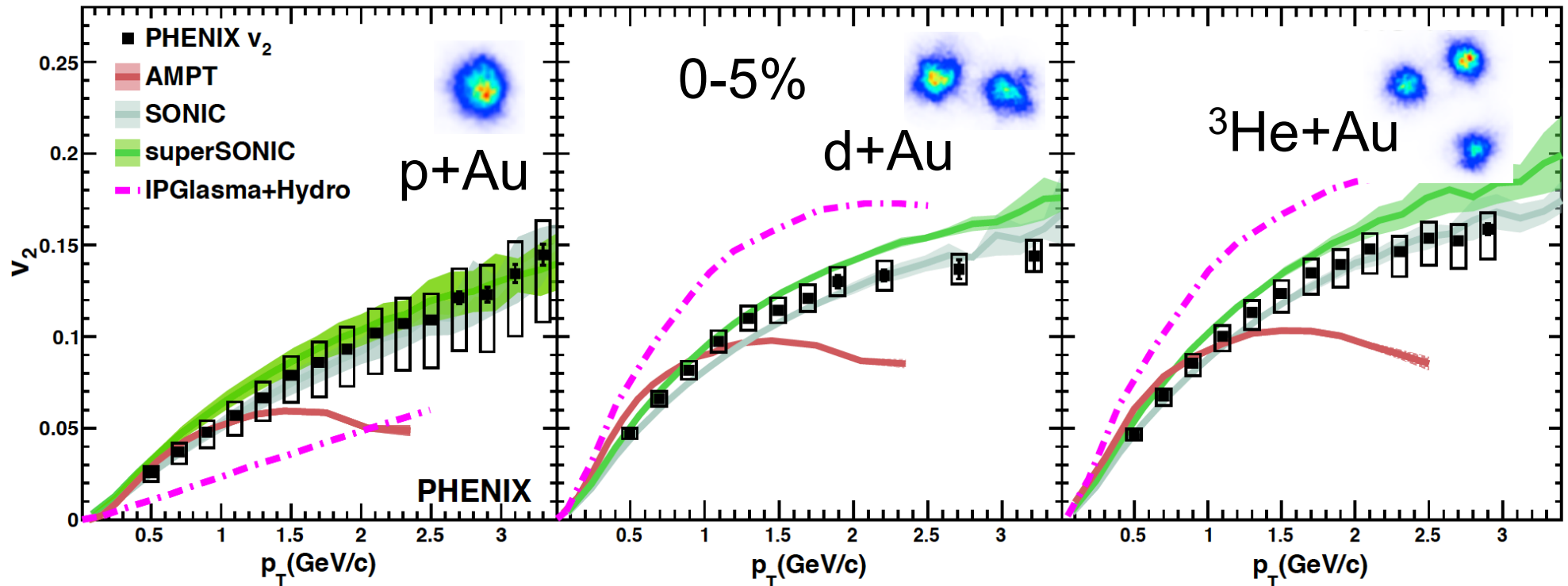


Collectivity in small systems at RHIC: geometry engineering at 200 GeV

[arXiv 1609.02894](https://arxiv.org/abs/1609.02894)

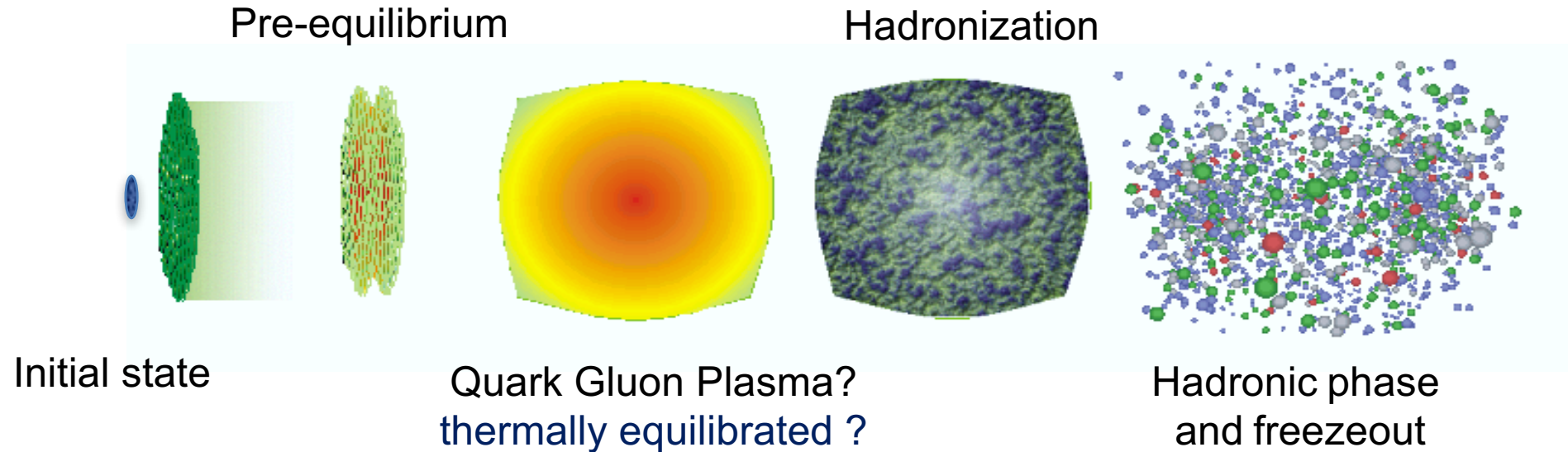
PRL 114, 192301, (2015)

PRL 115, 142301, (2015)



- Hydrodynamics works!
- AMPT: weakly coupled partonic cascade+quark coalescence+hadronic cascade also works at low p_T . Why?
- What other knobs can we turn to understand the origin?

Why study small systems in a BES ?



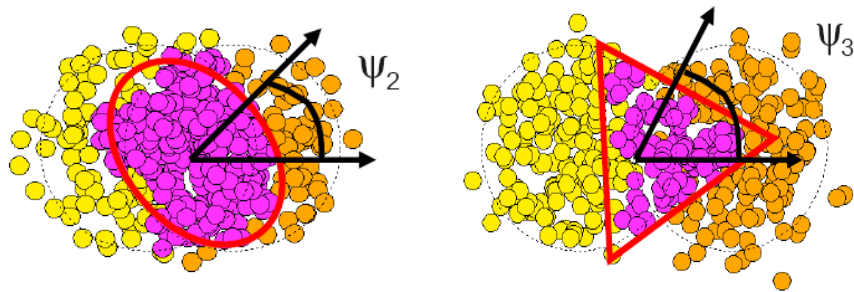
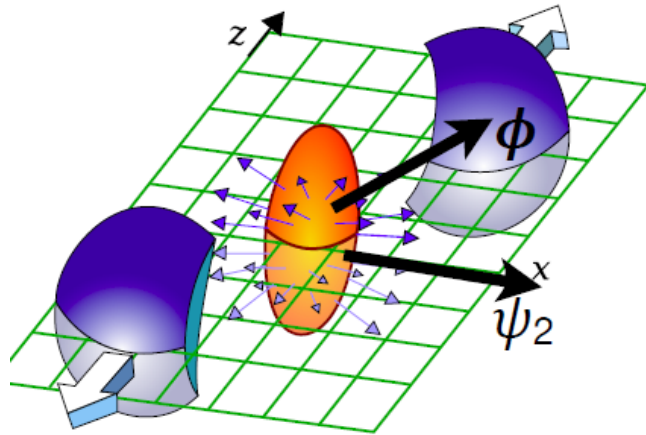
- The time spent in QGP is reduced with energy
- BES gives a good handle to understand the role of pre-equilibrium and hadronic flow
- Study of the pseudorapidity dependence
 - to gain insight in the longitudinal dynamics
 - discriminate between initial state models
- Run 16 d+Au: 200, 62, 39, 20 GeV

Experimental methods in PHENIX

Event plane: determined at large backward pseudorapidity
Particles: tracked over a large pseudorapidity range



$$dN / d\phi = 1 + \sum_n 2v_n \cos(n(\phi - \Psi_n))$$



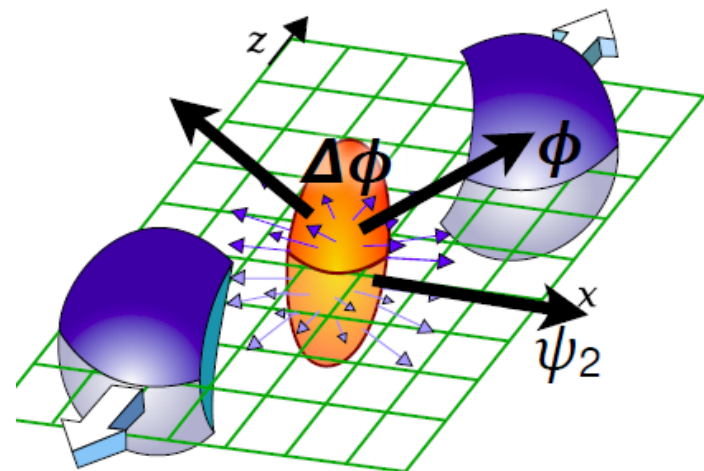
Or

2-particle correlations comprised of:

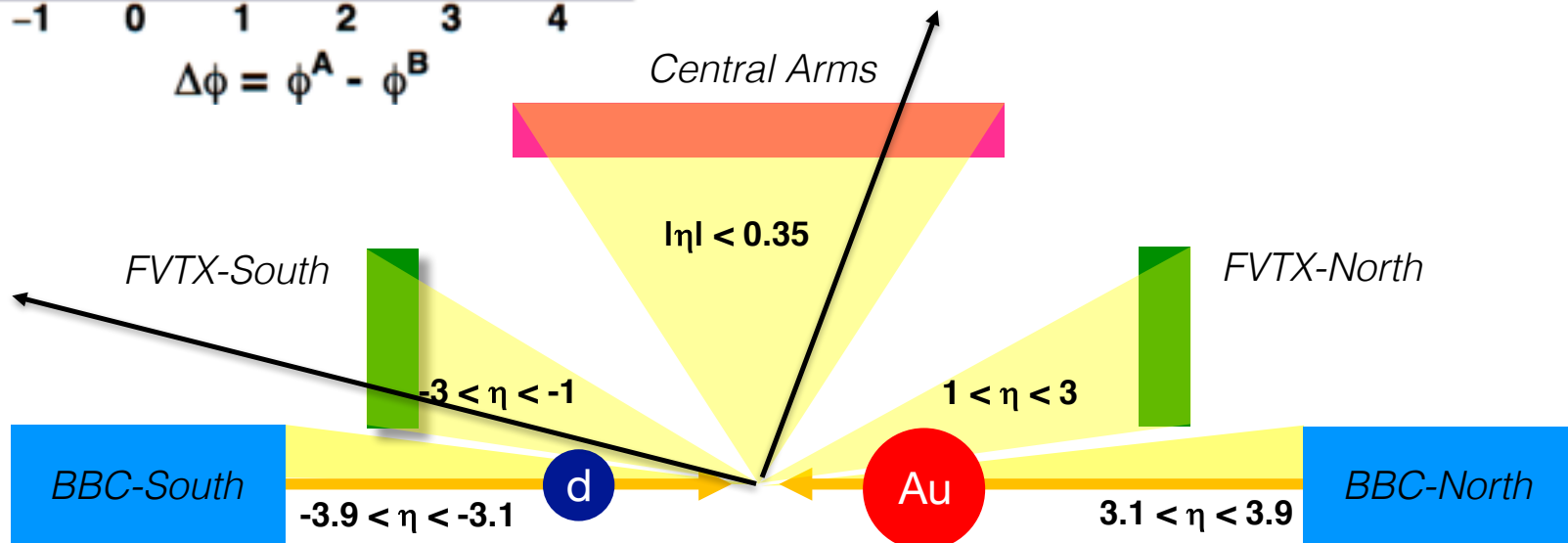
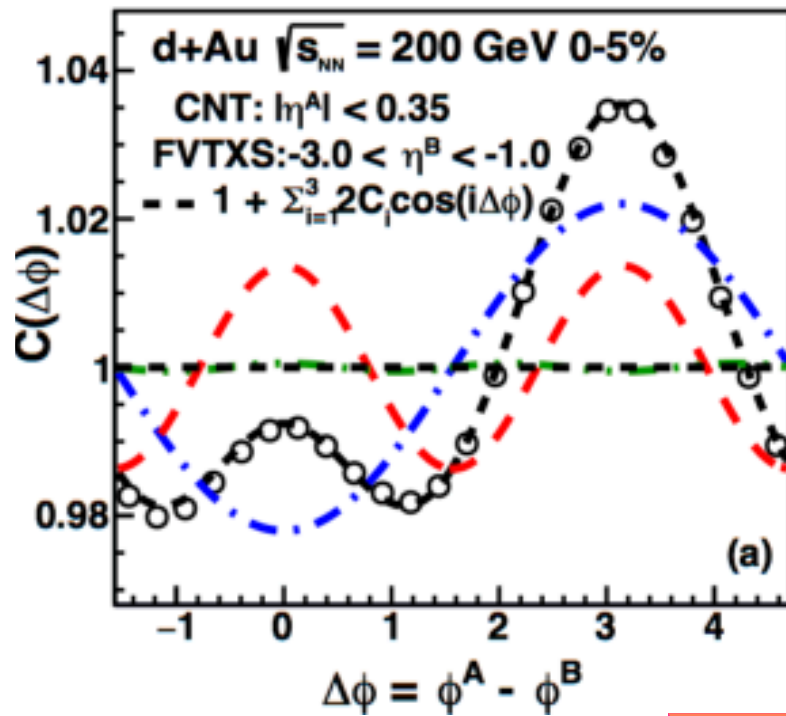
- 1) particle at midrapidity
- 2) energy cluster in BBC
- 3) tracks in FVTX

pair amplitude modulation

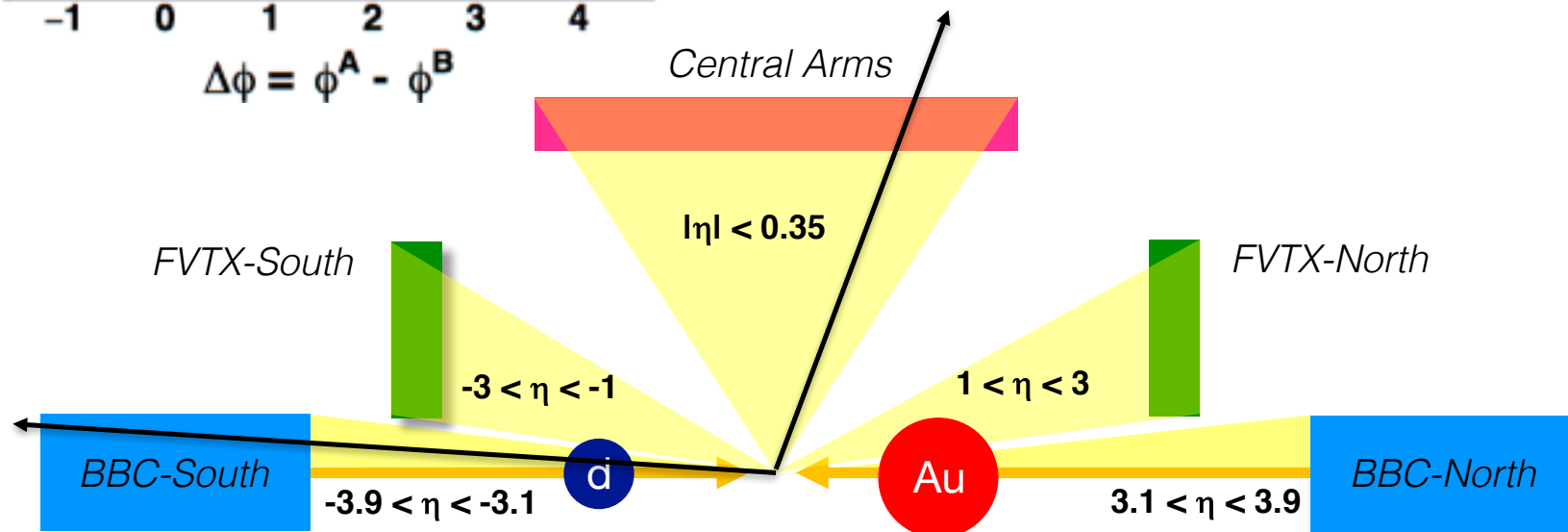
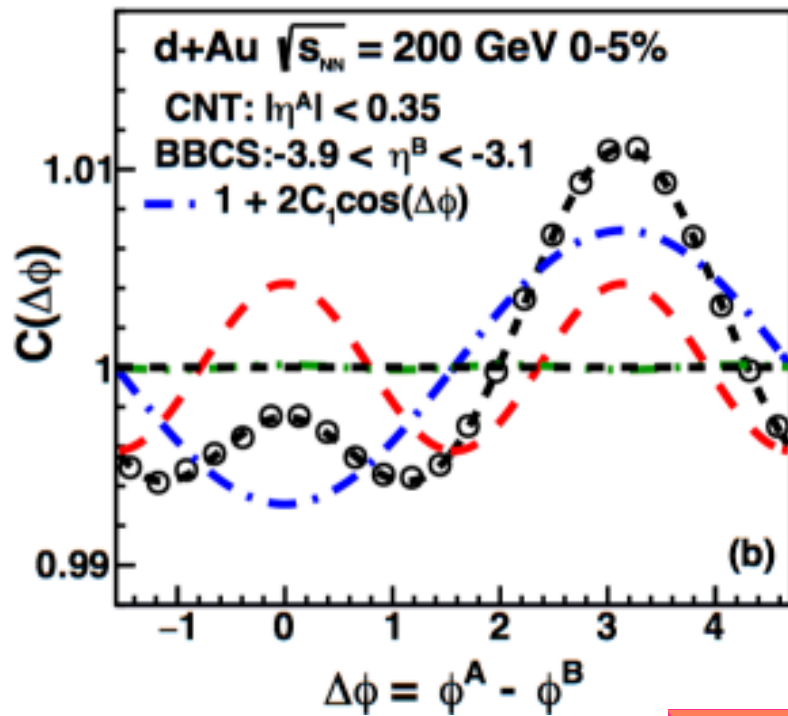
$$C_n = v_n^a \times v_n^b$$



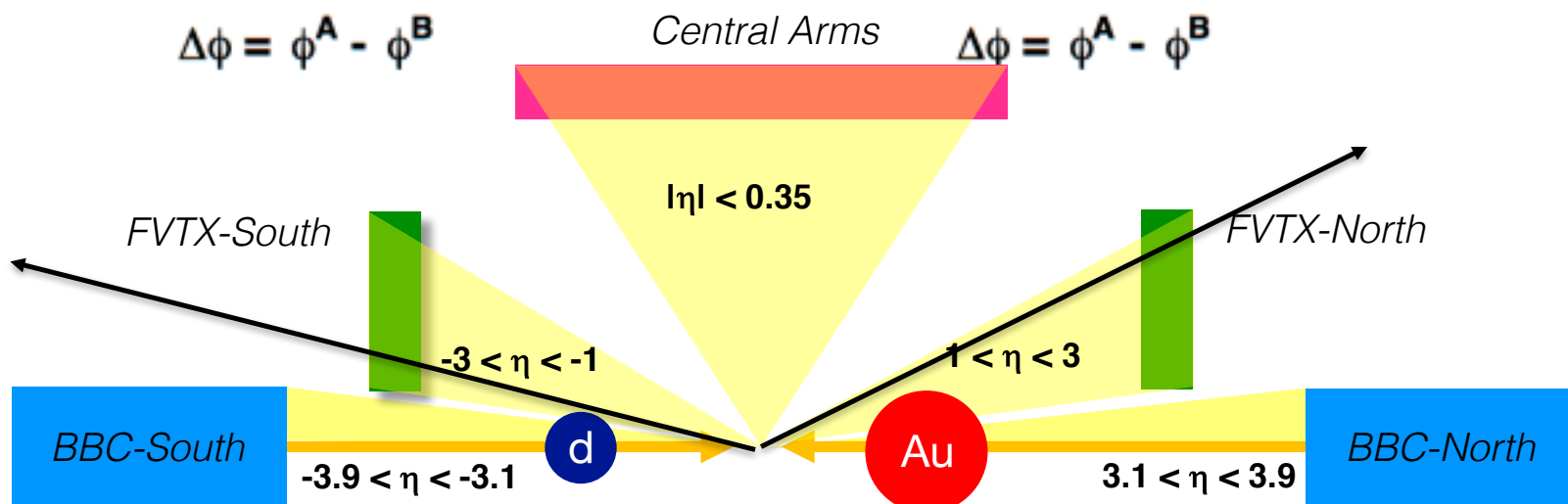
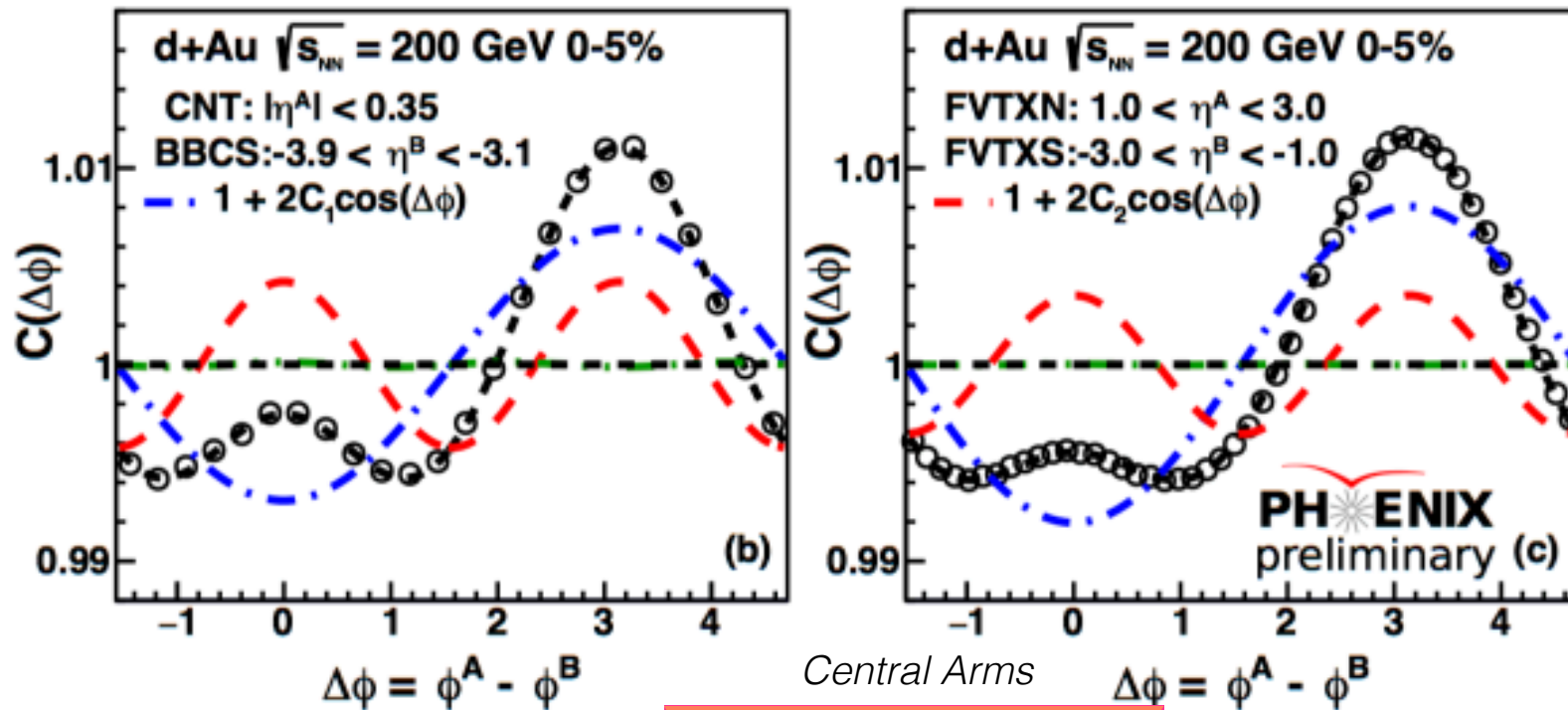
d+Au at 200 GeV: 2-particle correlations



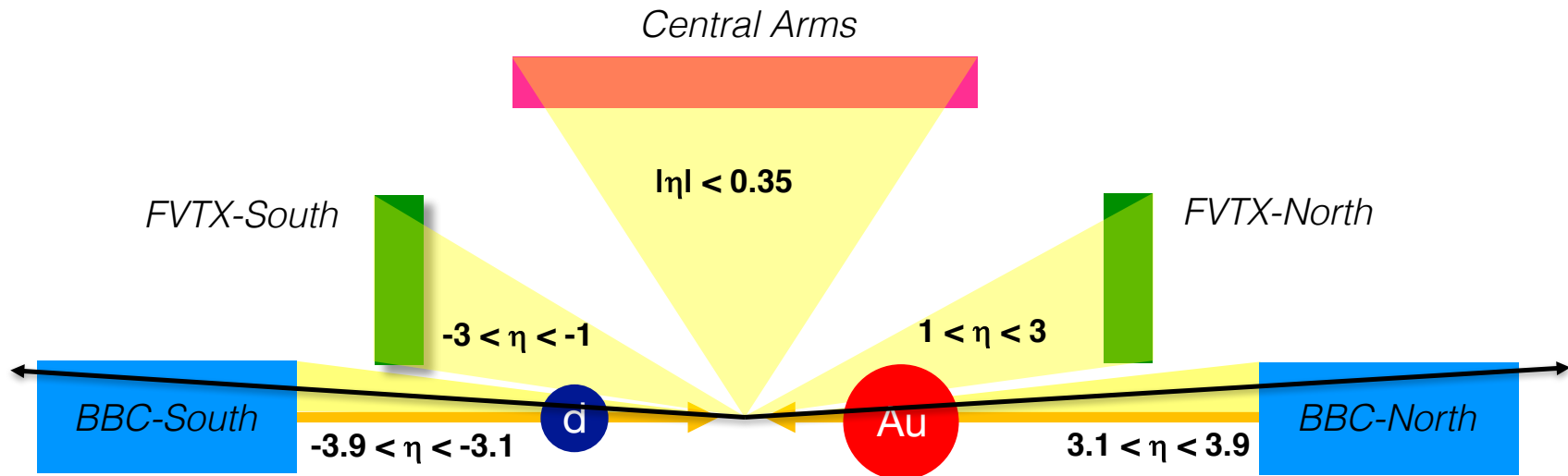
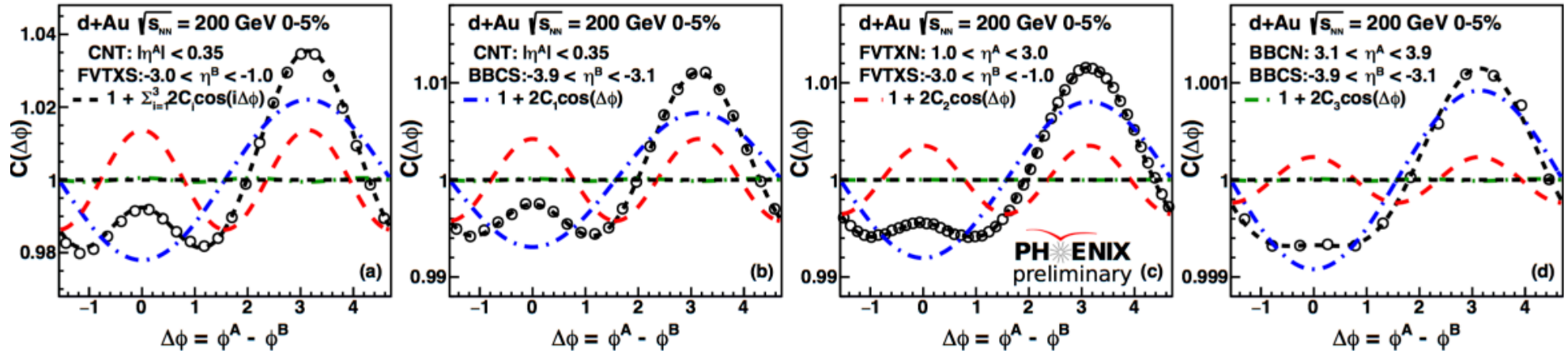
d+Au at 200 GeV: 2-particle correlations



d+Au at 200 GeV: 2-particle correlations



d+Au at 200 GeV: 2-particle correlations



A clear ridge is seen with all detector combinations, even for $\Delta\eta > 6.2$

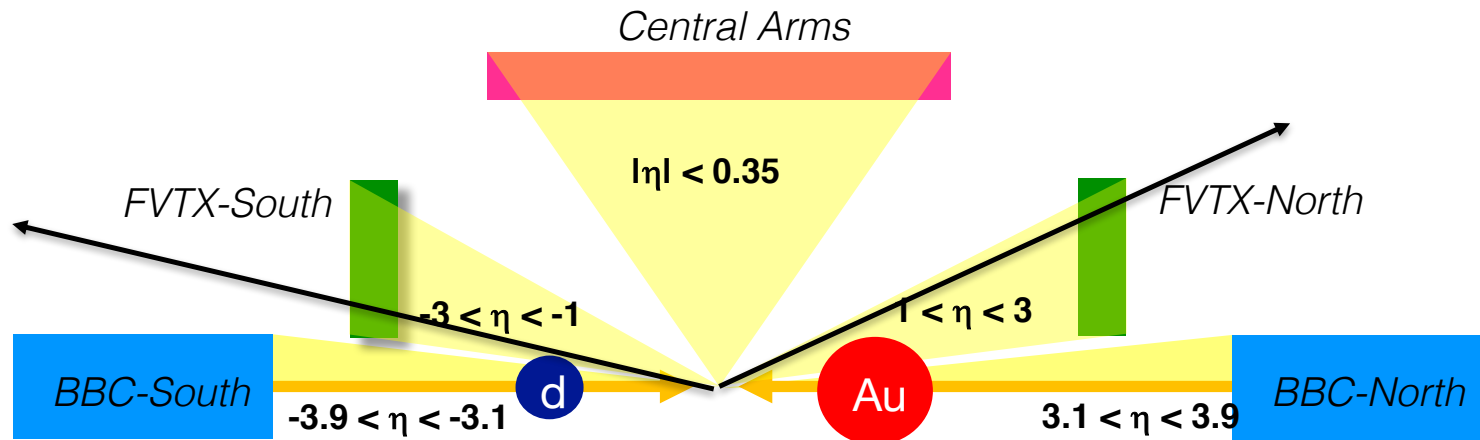
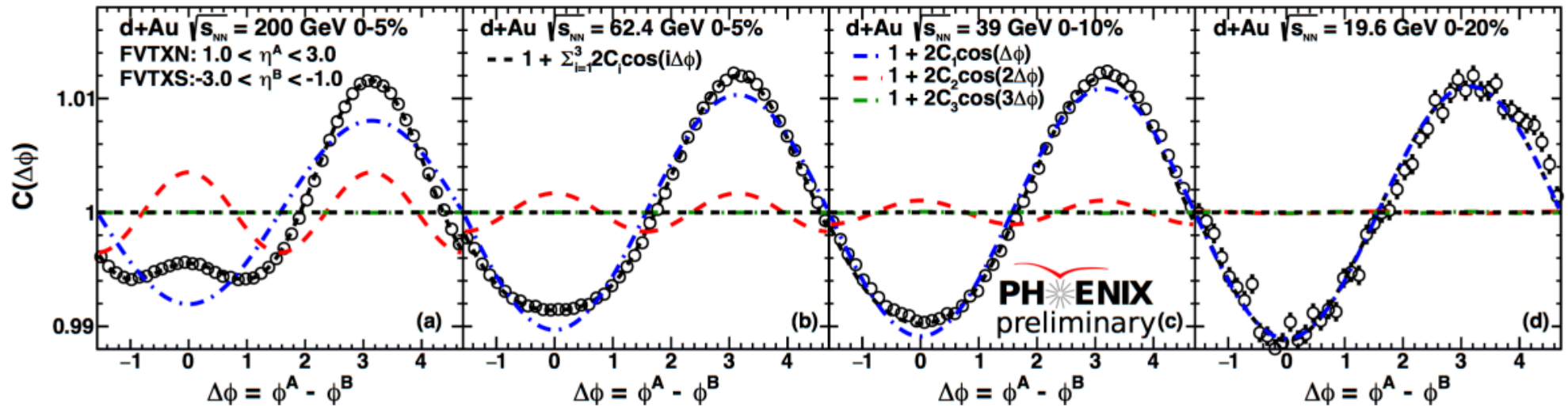
Energy dependence of ridge in d+Au

200 GeV

62 GeV

39 GeV

20 GeV



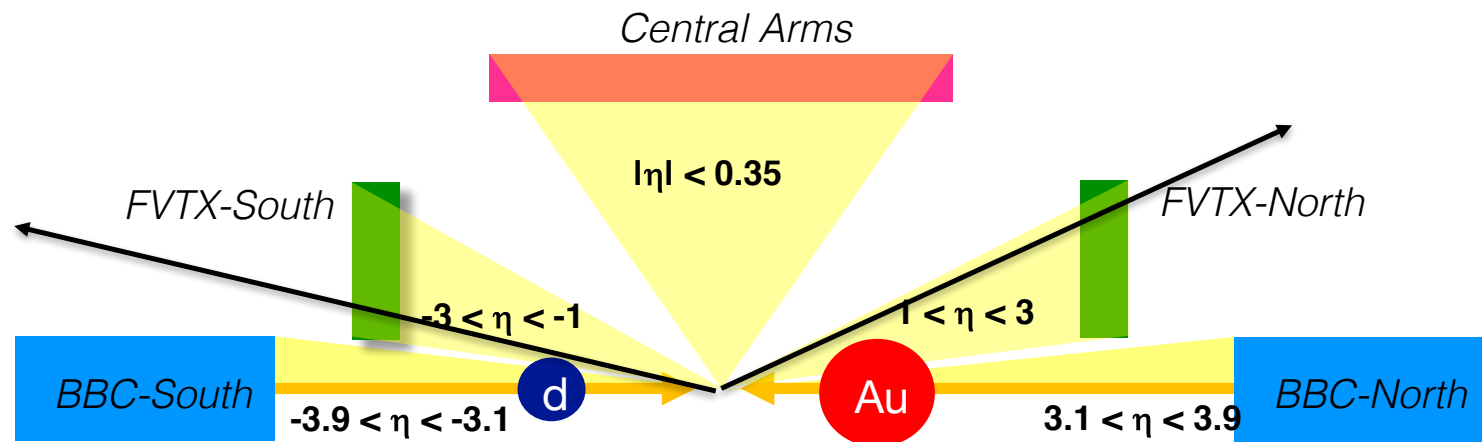
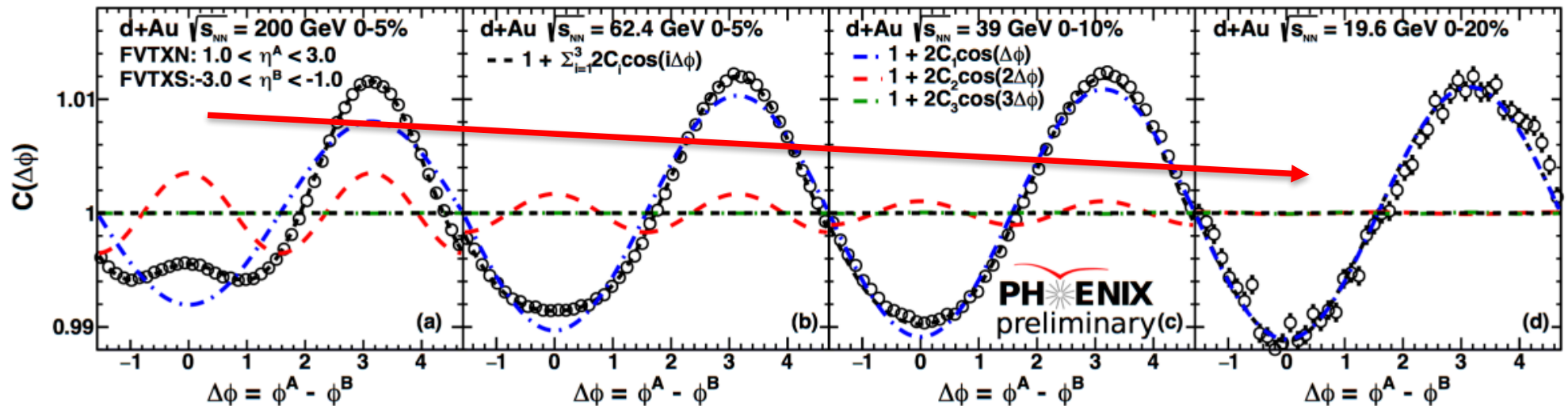
Energy dependence of ridge in d+Au

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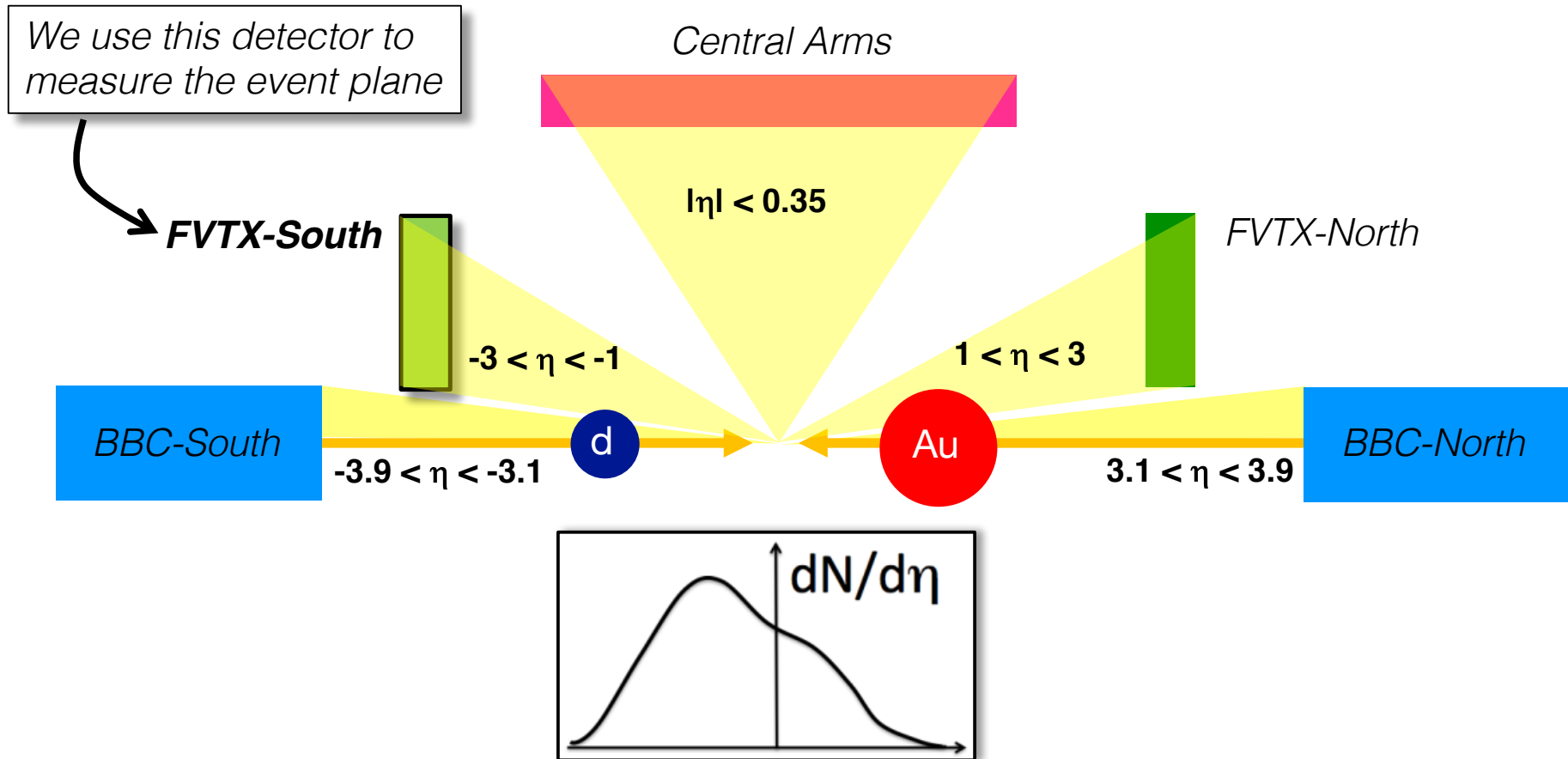
39 GeV

20 GeV



The c_2 amplitude decreases with energy,
but so do multiplicity and resolution.

Event plane measurements



$$v_2 = \frac{\langle \cos 2(\phi - \Psi_2) \rangle}{\text{Res}(\Psi_2)}$$

To optimize Resolution, we use:

- Central Arms
- FVTX-South
- BBC-South

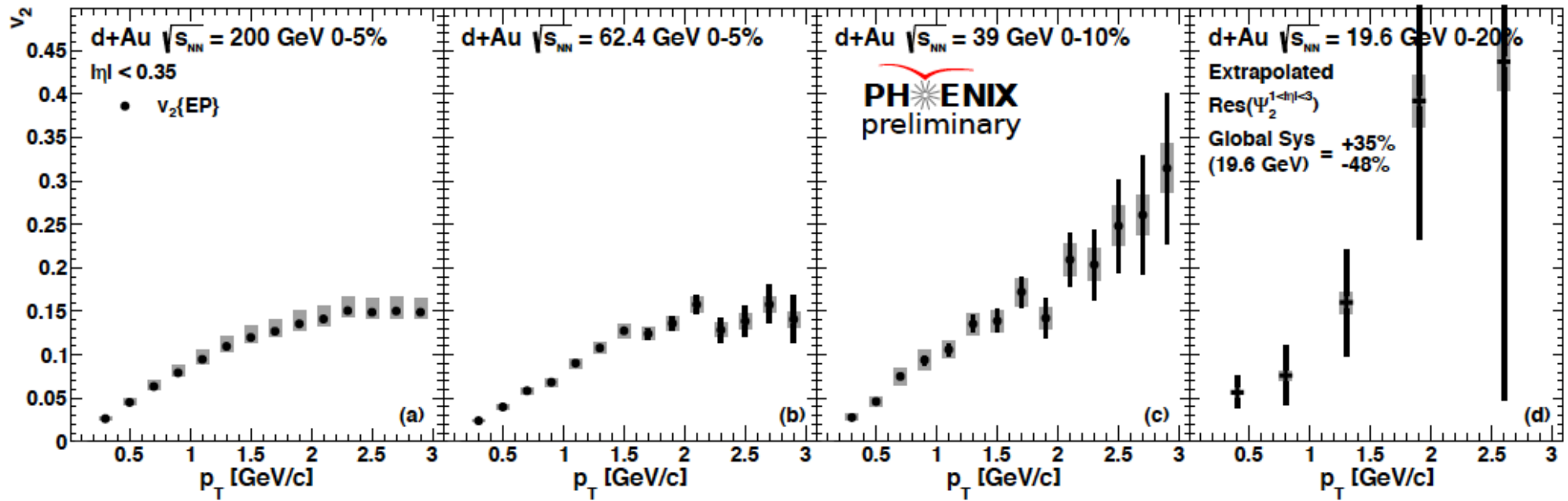
Midrapidity event-plane measurements of v_2

200 GeV

62 GeV

39 GeV

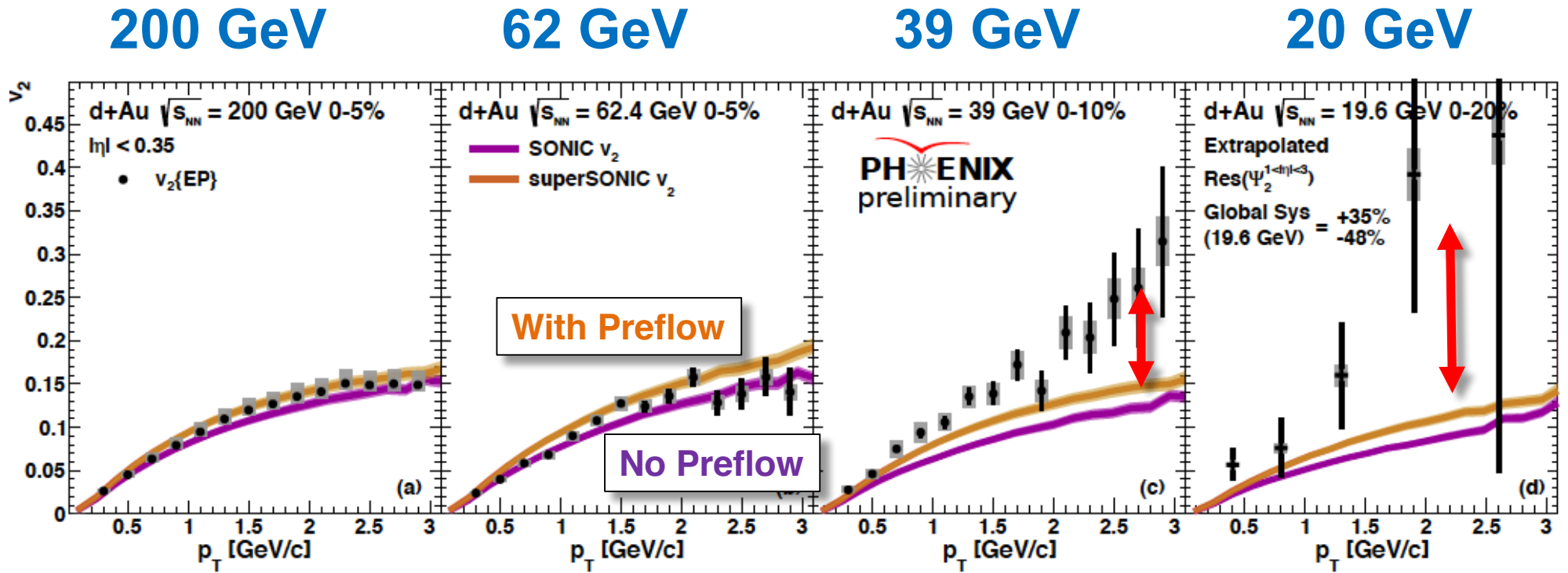
20 GeV



Nearly identical

Increase at high p_T ?

Event plane measurements of v_2



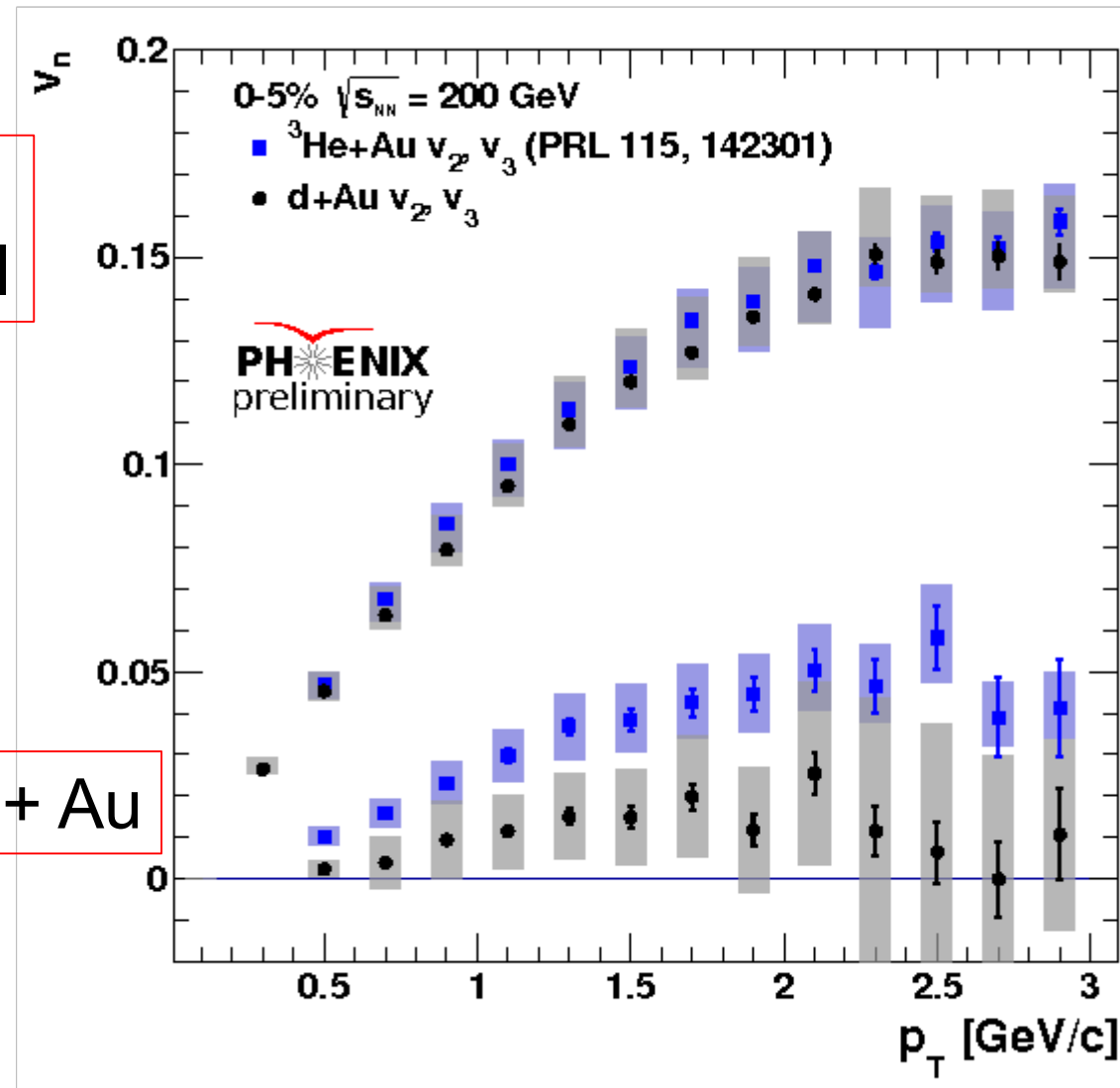
Nearly identical
 Well described by hydro
 No clear trend with preflow

Increase at high p_T ?
 Nonflow ?

Triangular flow at 200 GeV in different systems: insights about the role of preflow

v_2 in d/ ^3He + Au
Nearly identical

v_3 smaller in d+ Au



v_2



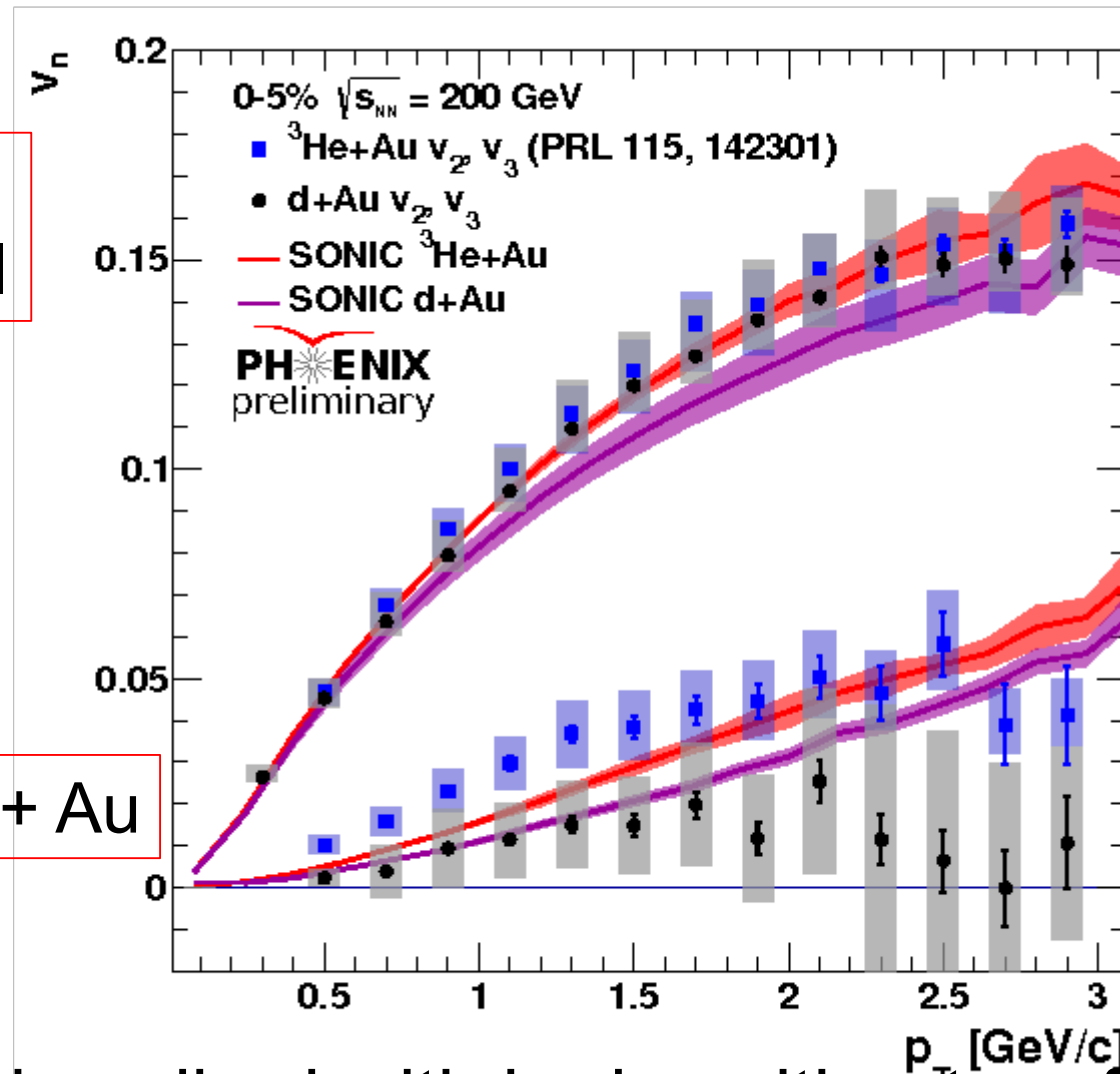
v_3



Triangular flow at 200 GeV in different systems: insights about the role of preflow

v_2 in d/ ^3He + Au
Nearly identical

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v_2

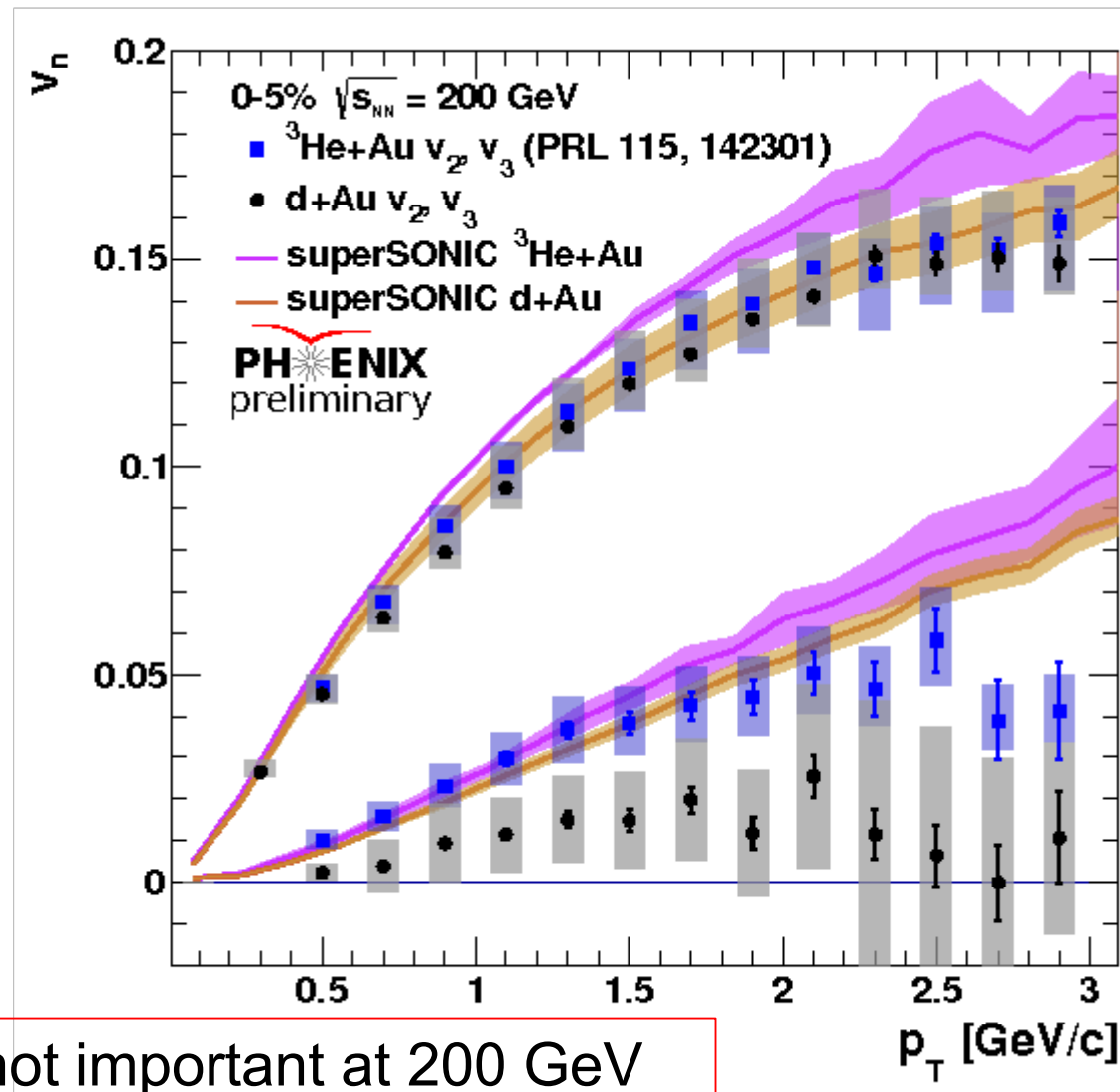


v_3



- Trends well described with hydro without preflow

Is there pre-equilibrium flow ?



Preflow seems not important at 200 GeV

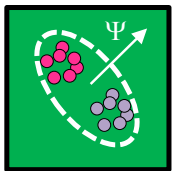
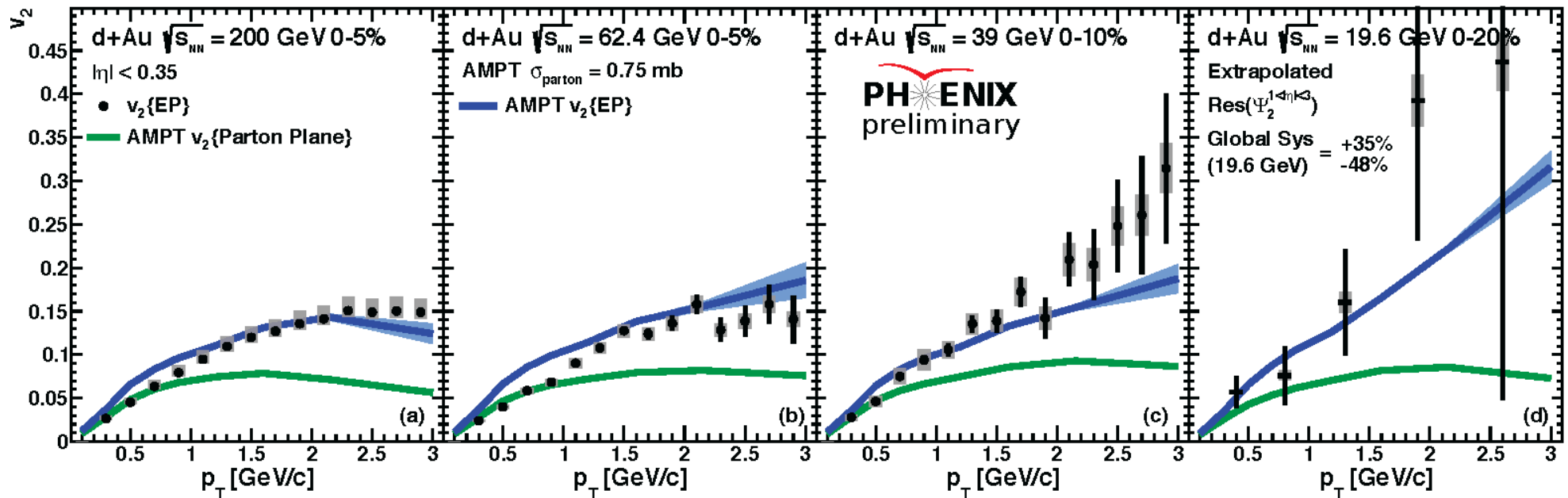
Nonflow correlations: insights from AMPT

200 GeV

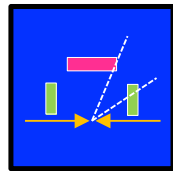
62 GeV

39 GeV

20 GeV



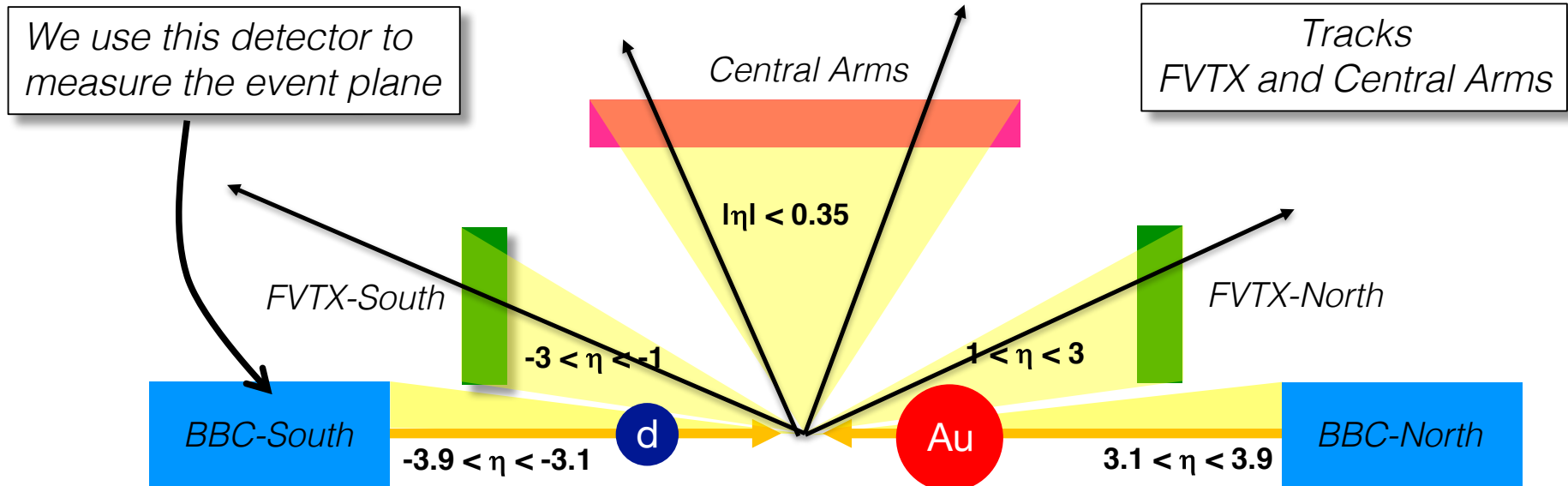
Pure Flow



With Non-Flow

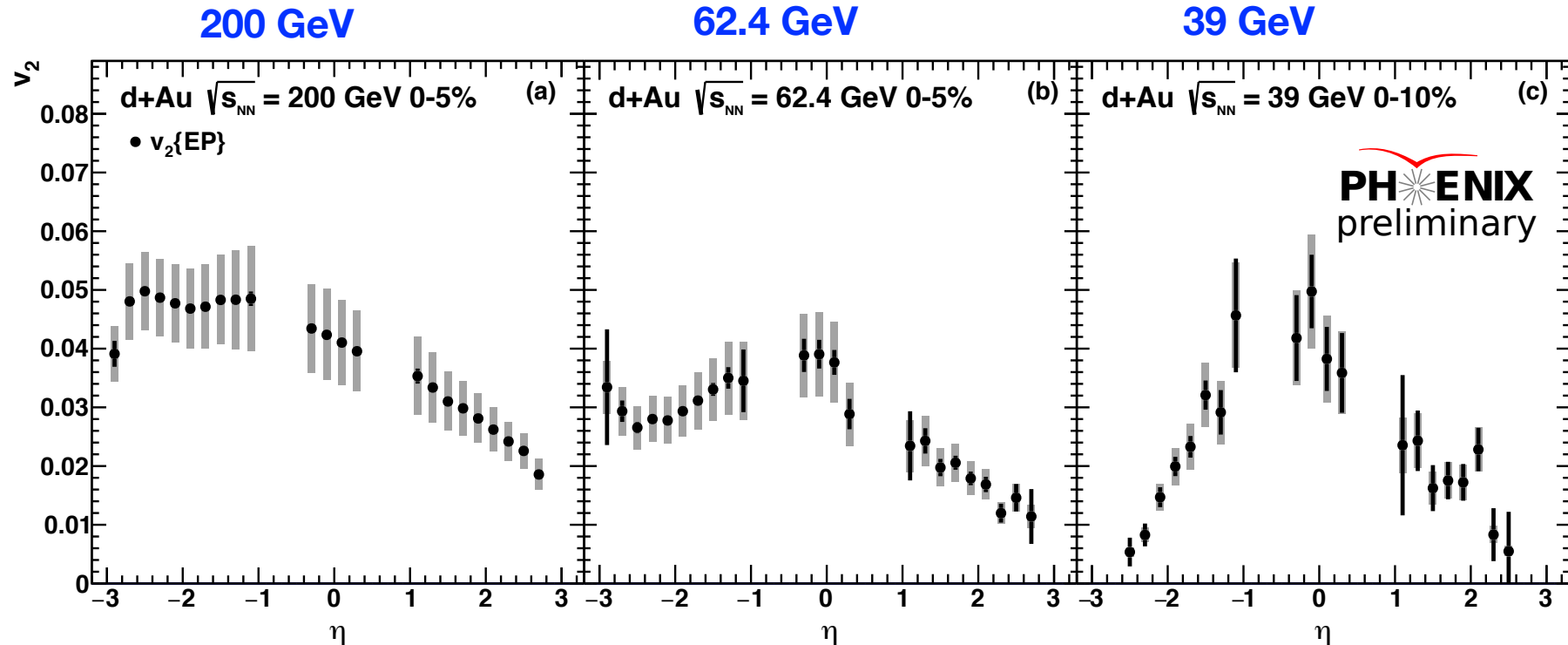
- Evidence for collective effects down to 39 GeV
- Nonflow correlations at 20 GeV require further studies

v_2 vs η : analysis method

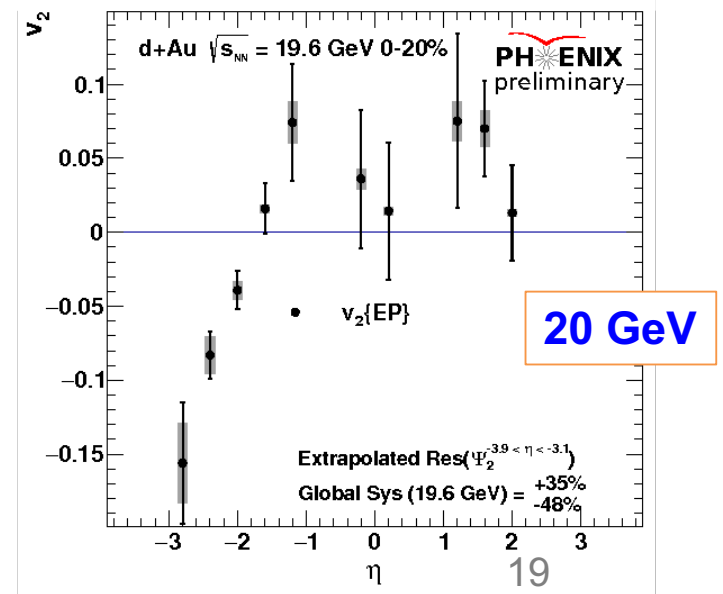


- We want to measure integrated v_2 ($0 < p_T < \infty$)
- No p_T information available from FVTX
- Devise a correction based on AMPT

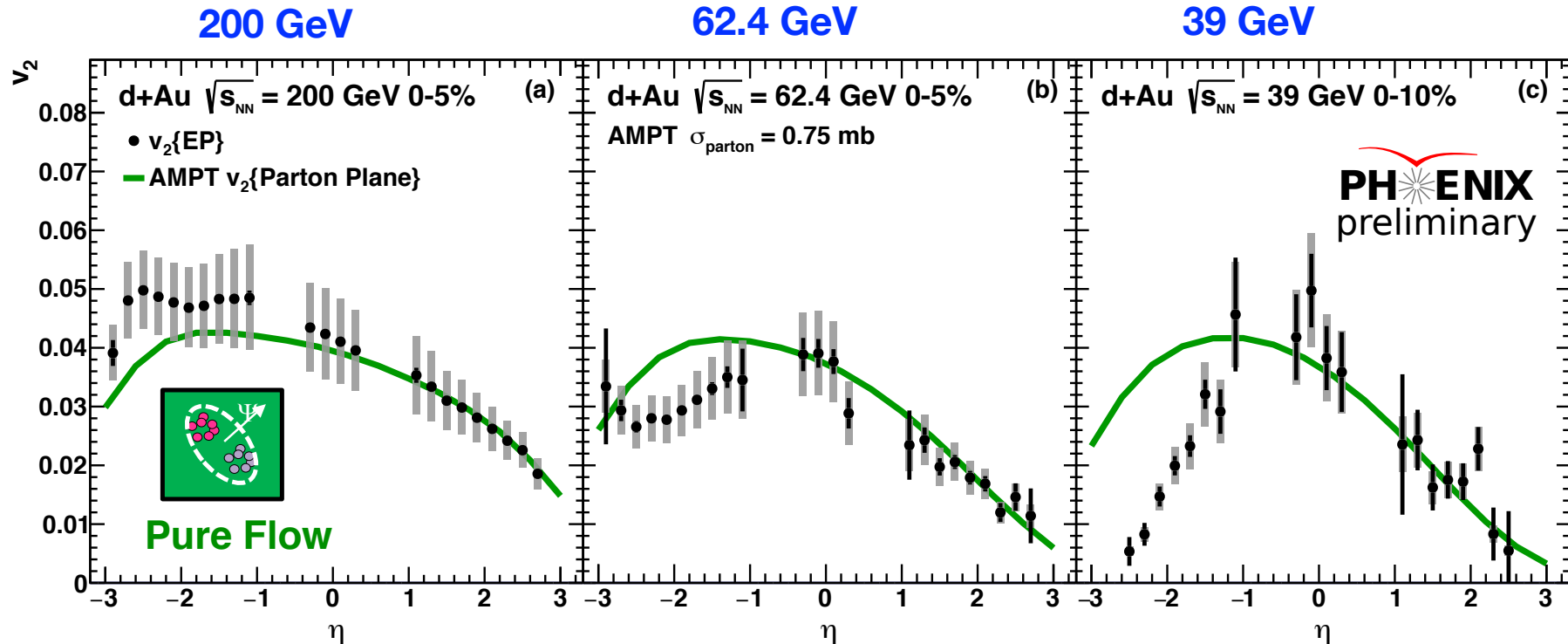
v_2 vs η



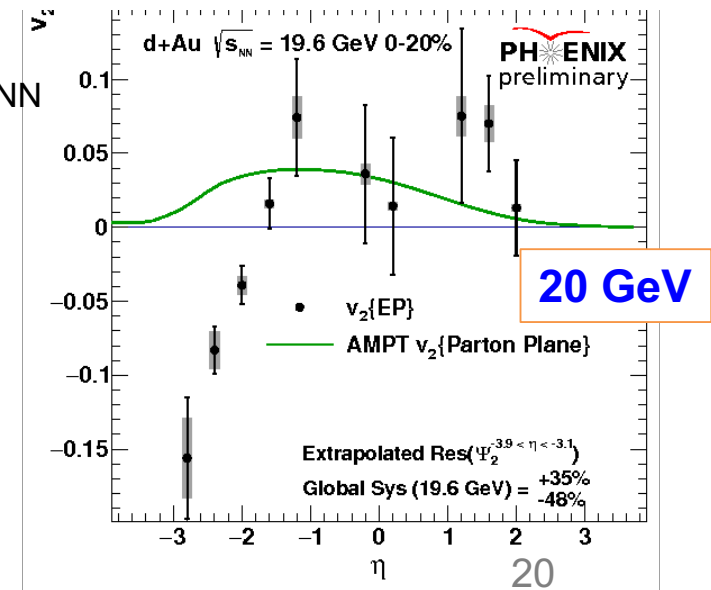
- Forward: similar values at all $\sqrt{s_{NN}}$
- Backward: decrease with $\sqrt{s_{NN}}$



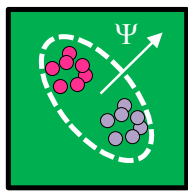
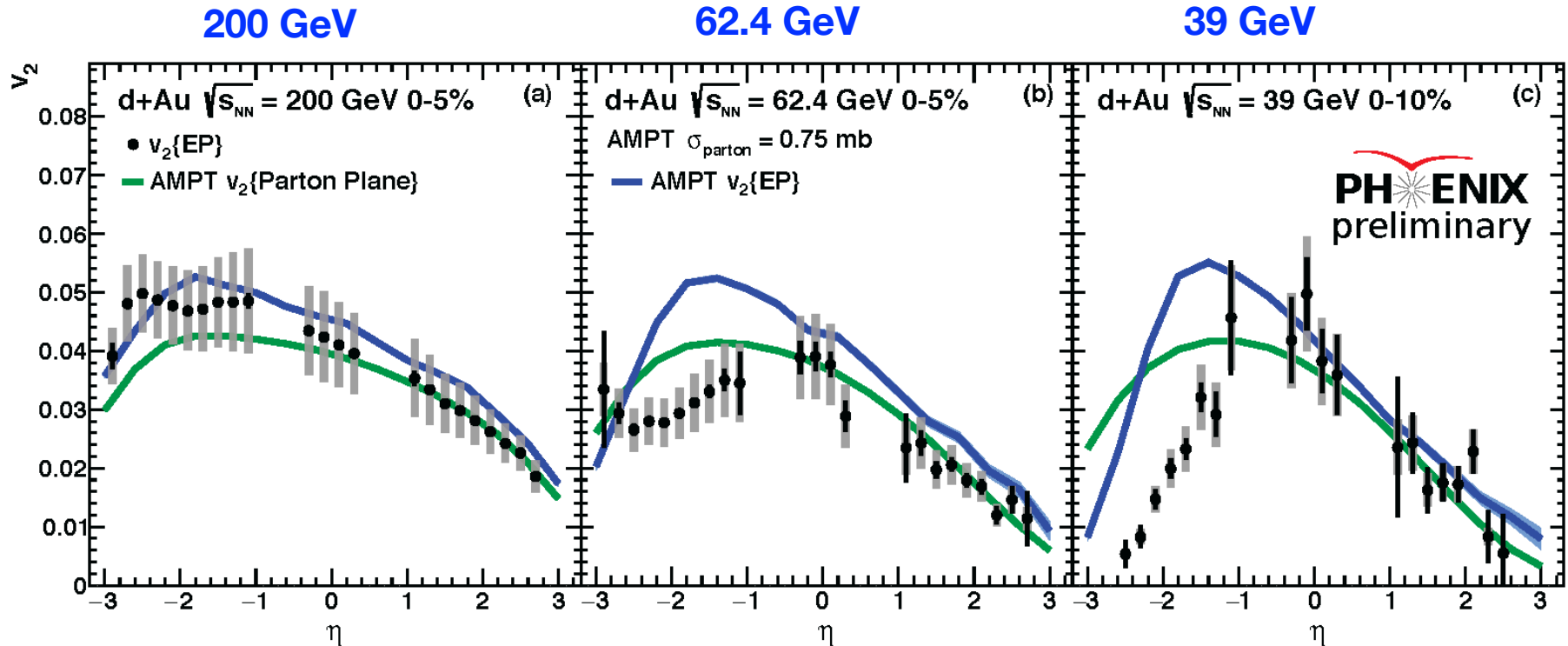
Insights from AMPT



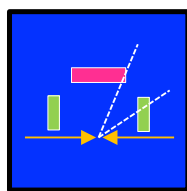
- Forward: well described at all $\sqrt{s_{NN}}$
- Backward: AMPT deviates from data at low energy



Insights from AMPT

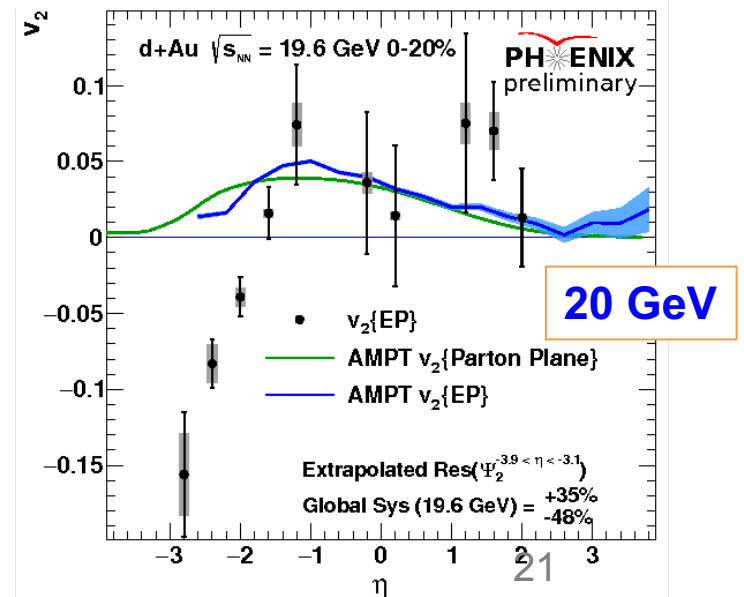


Pure Flow



With Non-Flow

- Flow dominates at forward and middle pseudorapidity



Summary

- In d+Au BES clear collective effects are observed in central collisions down to 39 GeV
- Interesting interplay between flow and nonflow correlations at 39 and 20 GeV d+Au
- Indication of flow in 20 GeV d+Au from $v_2\{4\}$
- At 200 GeV in d/ ^3He +Au collisions elliptic and triangular flow are well described with viscous hydrodynamics with small η/s
 - preflow contributions seem insignificant
- Stay tuned for more results at the lower energies

BACKUP

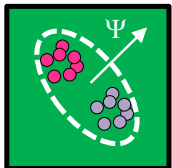
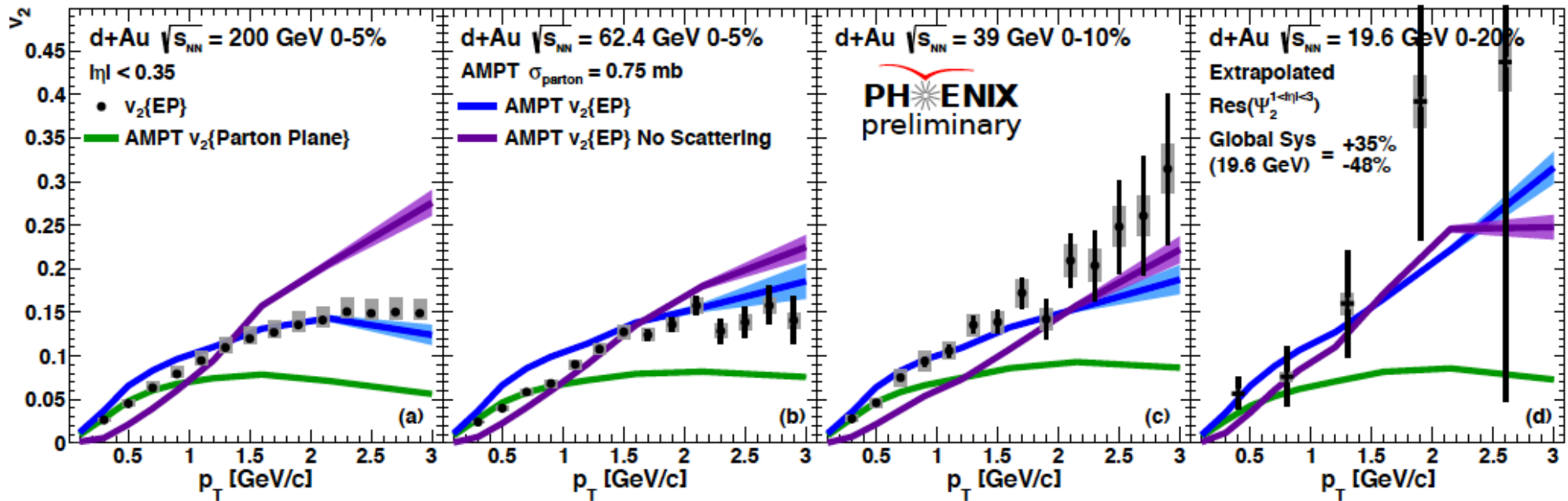
Nonflow correlations: insights from AMPT

200 GeV

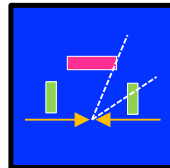
62 GeV

39 GeV

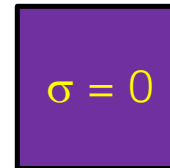
20 GeV



Pure Flow



With Non-Flow

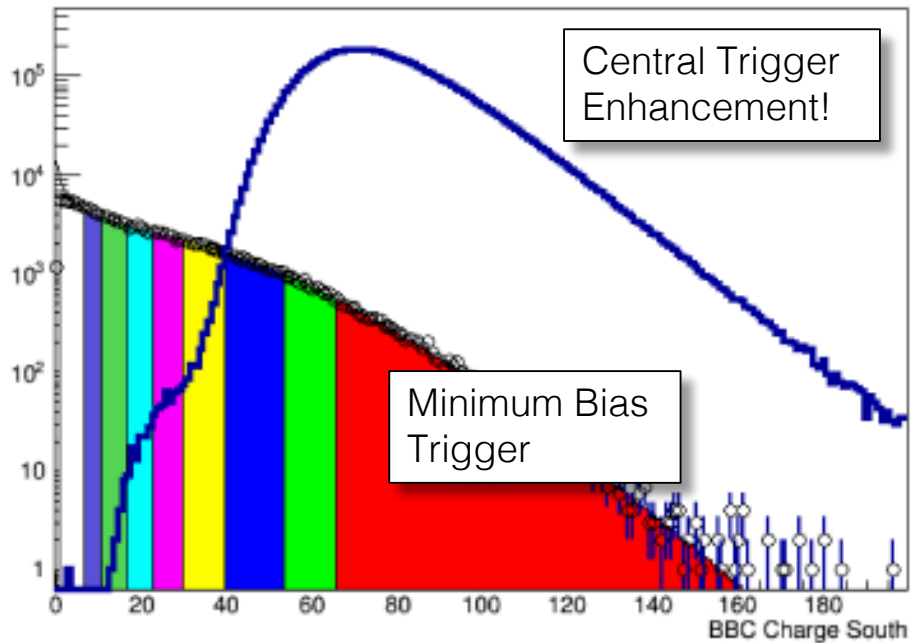


All Non-Flow

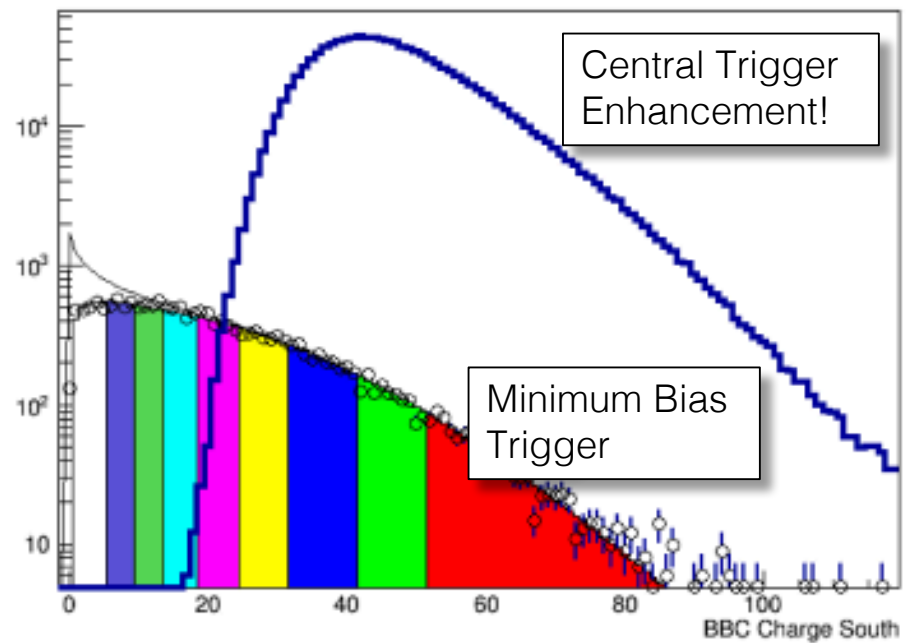
Evidence for collective effects down to 39 GeV
Nonflow correlations require further studies

Run 16 d+Au BES: Triggers

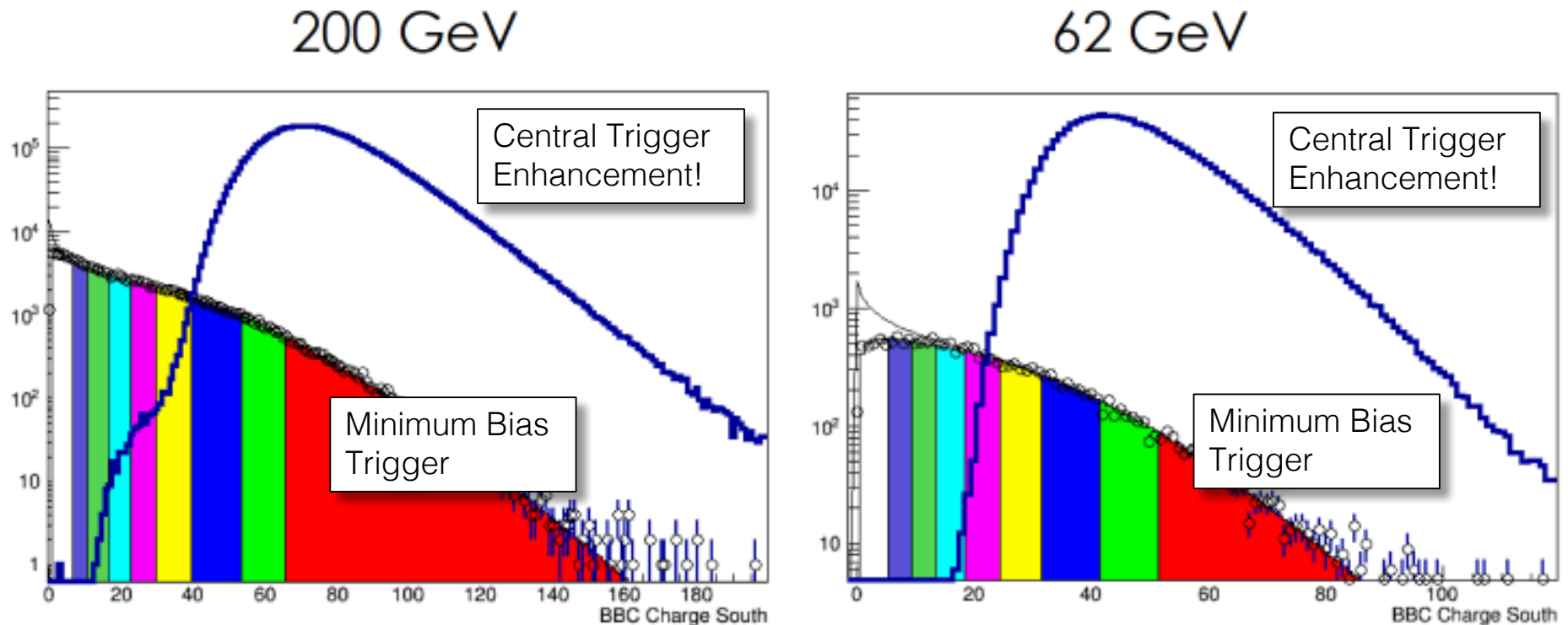
200 GeV



62 GeV



Run 16 d+Au BES: Event Sample Size



	Number of Central Events Recorded
20 GeV	15 Million
39 GeV	137 Million
62.4 GeV	131 Million
200 GeV	636 Million

v_2 vs η : analysis method

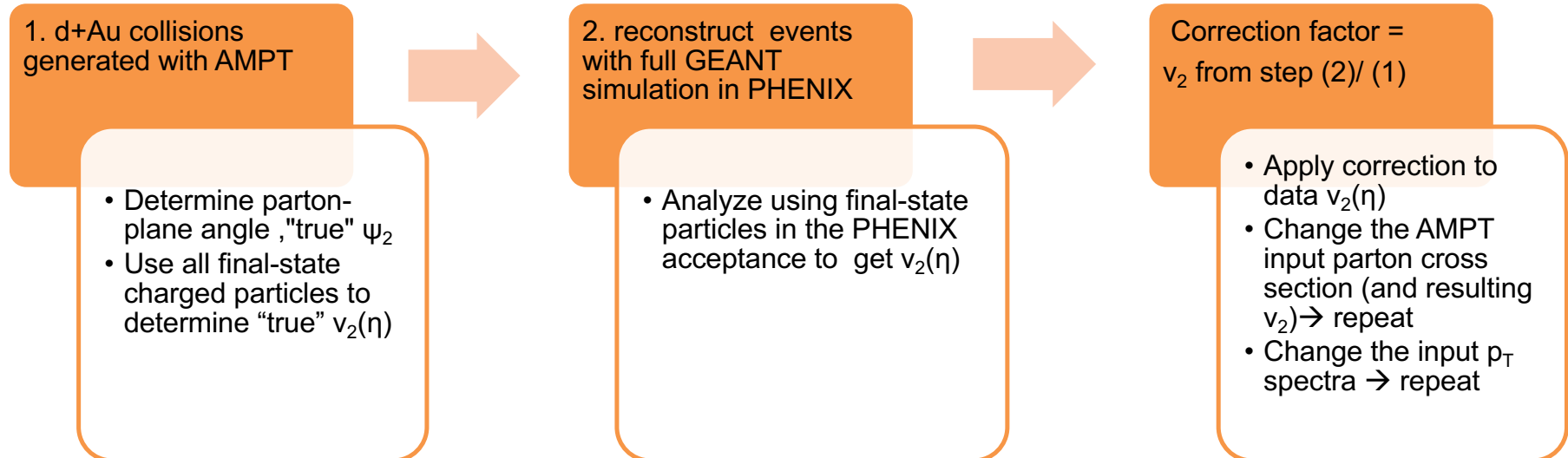
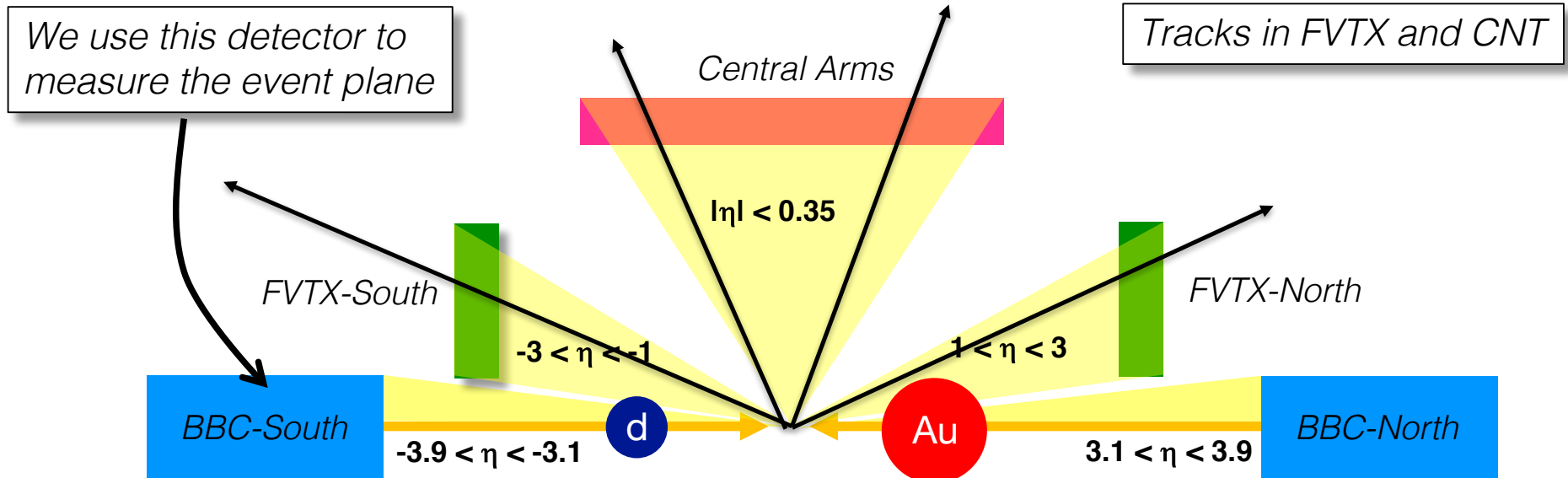


Table 6: Summary of the systematic uncertainties on the v_2 vs p_T measurements at 200, 62.4, and 39 GeV.

Sys	200	62.4	39
Double interactions	+9.4%	< 1%	< 1%
Event Plane	4.5%	4.5%	4.5%
East vs West	1.6%	3.6%	5.9%
PC3 Match	1%	1%	1%
ϕ shift	1%	1%	10% $p_T < 1$ and 5% $p_T > 1$
Total	$^{+10.6\%}_{-4.9\%}$	$\pm 5.8\%$	$\pm 7.5\%$

Table 8: A summary of the systematic uncertainties applied to the measurement of v_2 vs η in 200, 62.4, and 39 GeV d +Au collisions.

Sys	Type	200	62	39
Double Interactions	B	+2%	< 1%	< 1%
Event Plane	B	4.8%	4.8%	4.8%
Fake Tracks	B	3.3%	3.3%	3.3%
E vs W	B	1.6%	3.6%	5.9%
AMPT correction	B	$\sim 0 - 3\%$	$\sim 0 - 3\%$	$\sim 0 - 3\%$
Total (approx.)	B	$^{+8\%}_{-7\%}$	$\pm 8\%$	$\pm 9\%$

